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Agricultural Research

Building a Better Soybean

The Miracle Crop Just Keeps on Growing

Like the old farm saying about utilizing every part of a pig but its squeal, soybeans have found their way into an eye-opening array of products, edible and otherwise.

Starting with the basics in nutrition, there's milk—not cow's milk, but soy milk. In the United States, soy milk is used in infant formulas, and it's stocked in health food stores as well.

Soy milk plays an even more important role in human nutrition in other parts of the world. In China, it's called tou chaing, and cafes there that specialize in this beverage often have an open pot of boiling tou chaing in front of the shop to lure customers, in much the same way sizzling onion bits on a grill make mouths water on a carnival midway.

A soybean food product that's probably more familiar to the average American consumer is tofu, soybean curd made by coagulating soy milk. Far from being just a fad, tofu—also spelled tou fu—dates back many centuries. One popular recipe for preparing tofu was developed by Liu An, King of Wainan, sometime between 179 and 122 B.C.

Today, there are also soy yogurt, soyburgers, soy loaf, and soy sausage. Soy oil is the most widely used edible oil in the United States; you can find it in mayonnaise, salad dressing, whipping cream, and dessert frostings. Soy components such as protein and oil are ingredients in dozens of everyday foods—from the granola bar at breakfast and the potato chips at lunch, to a late-night snack of ice cream—and it's almost impossible to find a chocolate treat minus soy lecithin.

Thanks to research by ARS scientists, soybeans have been incorporated into many common nonfood products ranging from the morning newspaper printed with soy oil-based ink to cleaners capable of lifting grease, catsup, mustard, ink, lipstick, and mascara stains from fabric. It's difficult to imagine a day without soybeans.

But soybeans actually got off to a slow start in the United States. Although they arrived here in the mid-1700's, they didn't really catch on until the 1920's.

Demand for soy products was already on the rise: The United States imported 23.5 million pounds of soybean oil in 1927. But farmers were still cautious about trying this new crop. At that year's Tama County (Iowa) fair, first prize for an exhibit went to a display that promoted soybeans' potential as a cash and feed crop and proclaimed soybeans "The New Iowa Dollar."

In the 1927 Yearbook of Agriculture, Secretary of Agriculture W.M. Jardine had this to report to the President and to the farmers he hoped would be the chief beneficiaries of the book:

"During the past year many new varieties of soy beans have been received from our agricultural explorers. . . . The adaptability of the soy bean to new conditions is well illustrated by the Virginia variety. In the Ozark region of Missouri, extensive tests failed to show any promising sorts until the Virginia was tried and found to succeed admirably on the less fertile Ozark soils. The range of local adaptability is extensive and the study of varieties must be carried on over a wide territory."

More than 65 years later, farmers still strive to plant just the right variety of soybean for a specific setting, even to the extent of planting beans of varying maturity dates at different locations in a single state.

But science is working to manipulate the soybean in more sophisticated ways. At one ARS laboratory at Beltsville, Maryland, scientists have cloned genes for proteins in soybeans, with an eye to improving the quality of the beans' oil.

The scientists want to pinpoint what turns these genes on and off, since they prompt production of the proteins which, in turn, are involved in production and packaging of the oil inside the bean. The researchers also want to know how factors such as drought and heat stress affect the activity of the genes.

At another Beltsville lab, ARS scientists are studying the gene that controls when soybean plants shed their flowers, frequently in response to drought or other stresses. Fewer flowers mean fewer beans.

The gene in question orders cells to make an enzyme called cellulase. Flowers are shed when cellulase dissolves the biochemical glue between a single layer of stem cells and cells of the departing flower. The researchers hope to find the part of the gene that acts as its "on-off" switch.

The world is a much different place from the days when soybeans were touted as the Miracle Crop. But one thing hasn't changed: There are still plenty of scientific paths to explore on the way to achieving soybeans' full potential.

Sandy Miller Hays
ARS Information Staff

Agricultural Research

Sometimes called The Soybean Doctor in deference to his plant-breeding successes, agronomist Edgar E. Hartwig has devoted half a century to soybean research. His focus has been on developing productive plants with built-in resistance to insects, nematodes, and diseases. He is best known for commercial varieties that include Bragg, Lee, Forrest, Lamar, Sharkey, and most recently, Vernal. Photo by Keith Weller. (K5272-1)

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To Build a Better Soybean

Scientists still aren't through tinkering with this newcomer crop that's now second only to corn in importance to U.S. farmers.

Soybeans can be found today, in one form or another, in a wide array of food and industrial products. But until the early 1900's, soybeans were virtually unheard of in the United States. Those grown here were used as forage or as green manure to enrich the soil.

Much of the credit for creating a commercial market for soybeans is given to A.E. Staley, who, in 1922, modified his corn processing plant in Decatur, Illinois, and announced that he would buy all of the soybeans that could be grown.

Today, Staley would have his hands full: U.S. farmers in 1992 produced nearly 2.2 billion bushels of this versatile crop on more than 62 million acres in 26 states.

"As the potential uses for soy-based products increase, there is a desire to breed new soybean varieties to meet specific market needs," says Howard J. Brooks, associate deputy administrator of plant sciences for USDA's Agricultural Research Service.

Whether it's increasing yields, breeding plants that are genetically resistant to pests, or boosting protein and oil levels in soybeans, ARS researchers throughout the country have a significant hand in soybean production.

For agronomist Joseph Burton at the ARS Soybean and Nitrogen Fixation Research Laboratory in Raleigh, North Carolina, the goal is increasing the protein content of soybeans without decreasing yield.

"Usually, when soybeans are bred in an attempt to increase protein, total seed yield suffers," he says.

Soybeans' normal protein level is about 41 percent on a dry-weight basis. Burton has successfully upped this to 45.5 percent and is now working on the yield part of the problem.

With a classical breeding approach using restricted index selection, scientists are able to evaluate and select two or more traits simultaneously, instead of just one. They are having some success in increasing yields without affecting protein.

Burton has now completed six 2-year cycles in which 200 promising genotypes are planted in each of two locations. The best-yielding 10 percent, which also have higher seed protein concentrations, are then interbred and replanted. Using statistical analysis of seed yield and protein content, the scientists have developed an index for evaluating subsequent genotypes for the two desired characteristics.

"In past years, we've had yields that were only 5 percent less than Young, a currently planted commercial soybean variety, but with about a 46-percent protein level," Burton says.

Potential markets for high-protein varieties include the animal feed industry and producers of soy-based food for human consumption.

KEITH WELLER

ARS plant pathologist Greg Noel (left) and professor Cecil Nickell, University of Illinois, Urbana, evaluate soybean roots for SCN resistance. (K5243-11)

Mapping Soybeans' Future

In the future, making decisions to guide soy breeding programs such as Burton's may be as simple as consulting a map.

A team of ARS scientists at Ames, Iowa, is mapping the soybean genome to determine the whereabouts of the genes on its chromosomes. Plant geneticist Randy C. Shoemaker says having such a map will "take some of the gamble out of genetics.

"Breeders are tossing the dice every time they make a cross," he says. "We want to stack the deck in our favor."

Just as mile markers can tell you where you are on a highway, these genome maps can tell a scientist where to find the genes responsible for economically important traits such as the protein and oil contents of the soybean seed.

These are both quantitative traits, Shoemaker explains, which means that more than just a single gene determine the levels produced. So scientists are using molecular probes that distinguish specific fragments of DNA to identify the genes responsible for the protein and oil content.

Genetic maps will allow breeders to identify key genes that will, in turn, help them successfully combine multiple traits to make advances much more quickly.

Thus far, Shoemaker and colleagues have mapped five of seven genes responsible for resistance/susceptibility to different races of phytophthora root rot, a disease that attacks the soybean's vascular system and eventually kills the plant. Phytophthora can cost growers a tremendous amount of money in lost yields.

"Using molecular probes, we analyzed six of the seven genes and were able to map five of them," Shoemaker says.

In Stoneville, Mississippi, scientists have found a new genetic source of resistance to phytophthora rot. A germplasm line that resists several races of the pathogen that causes the

disease was found in the USDA Soybean Germplasm Collection at Urbana, Illinois.

"This germplasm line contains a gene to fight phytophthora rot that is different from other genes currently being used by plant breeders to prevent the disease," says Thomas C. Kilen, the geneticist in charge of ARS' Soybean Production Research Unit at Stoneville. "It shows a resistance to some races of the pathogen that has not been seen in other lines."

Kilen has also found that the genes for phytophthora resistance and brown pod wall color are on the same chromosome, but not closely linked. By selecting for pod wall color, breeders may be able to indirectly select for phytophthora root rot resistance.

"The benefits of this will be limited, though, since the genes are not closely linked," Kilen says. "However, this knowledge will help further efforts to map the soybean genome."

Bad-Tasting Leaves

In other work at Stoneville, Kilen and coworkers have developed a new soybean with leaves that apparently taste so bad that insects, given a choice, won't bite into them. But the beans themselves are not altered, and the oil and meal taste fine.

Lavone Lambert, an entomologist at Stoneville, conducted studies that show the leaves and pods of this soybean plant contain a substance harmful to insects, but not to humans or livestock.

Mexican bean beetles, corn earworms, velvetbean caterpillars, soybean loopers, and beet armyworms—in fact, most major soybean insect enemies—do not fare well on the new variety.

Farmers may be able to save millions of dollars each year, just by planting the bad-tasting, pest-resistant bean. Insect damage, in terms of yield loss and control costs in only nine southern states, recently averaged more than $85 million.

"In addition to cost savings to farmers, the environment will benefit from less pollution if they don't have to use pesticides," says Kilen.

The hunt for insect-resistant soybeans has been ongoing for more than two decades, he adds.

Invisible Underground Attack

Warding off soil-borne nematodes is another important research goal.

KEITH WELLER

Roots infested with female soybean cyst nematodes (small round bodies); larger round nodules contain beneficial nitrogen-fixing bacteria. (K5244-6)

Several ARS scientists are searching for genes to incorporate into soybeans to better thwart *Heterodera glycines*, the soybean cyst nematode. There are nine known SCN races, or types, in the United States.

This minute worm invades roots, disrupting the flow of water and nutrients in the plants and reducing yields. Females are lemon-shaped and change in color from white to brown as they mature and die, to form cysts. The cysts are filled with eggs or hatched juveniles. The juveniles penetrate plant roots and develop into adults in about a month. As they develop, the females rupture the root surface.

The appearance of yellow, stunted plants in an oval formation in the field usually signals that soybean cyst nematodes have reduced normal root nodulation and root growth.

"Right now, the best way to fight this nematode is by crop rotation and using resistant varieties," says plant pathologist Gregory R. Noel, of the ARS Crop Protection Unit in Urbana.

Plants may be infested with SCN at any time during the growing season, but the most devastating attacks occur 1 to 2 months after planting. While chemicals are available to control the pest, prohibitive costs generally limit their use.

Some producers try to improve yields of SCN-stricken beans by irrigating. But Larry G. Heatherly, an agronomist at Stoneville, found that irrigation during the soybean reproductive period will not alleviate SCN stress.

"Growers with infested fields should be discouraged from expending resources to irrigate those fields," he says.

Both germplasm—soybean lines for use by breeders—and fully developed soybean varieties with new sources of SCN resistance are being developed by Noel and University of Illinois soybean breeder Cecil Nickell.

Since 1982, seven new varieties and four germplasm lines have been released. Some were developed with cooperation from the University of Missouri.

Lawrence D. Young, a plant pathologist in the ARS Nematology Research Unit in Jackson, Tennessee, released germplasm last year that resists the race 2 nematodes that primarily infest soybean fields in Maryland and Tennessee. The new soybean line also shows vary-

ing degrees of resistance to other nematode races.

"This line has good productivity, but the yield is not competitive with the best cultivars," said Young. "Our idea was to release the line so commercial breeders could cross it with their productive lines and give them nematode resistance."

Getting Enough Nitrogen

Like all living organisms, the soybean has specific needs that must be met for it to thrive. Carbon dioxide, sunlight, water, and nutrients are all "musts" for a healthy plant. Crops generally get their supply of nitrogen from the soil, but the soybean has another way to obtain this essential nutrient. A symbiotic nitrogen fixation system located in the roots takes gaseous nitrogen from the air and converts it to ammonium, a form usable by the plant.

To accomplish this, "A soil bacterium known as *Bradyrhizobium japonicum* invades the roots and forms nodules," explains James E. Harper, the plant physiologist in charge of the Plant Physiology and Genetics Research Unit at Urbana. "It's inside these nodules that nitrogen fixation takes place."

The bacteria obtain carbon compounds—primarily the common sugar sucrose—from the plant and return nitrogenous compounds to it, as well as to the soil.

Genetic selection has now pinpointed a mutant soybean line that has two to four times more nodules than the average plant. Harper is attempting to produce these extra nodules on a normal soybean root system to provide more nitrogen to the plant and possibly release more nitrogen to the soil.

Increased nodulation may be good news for farmers who plant corn in rotation after soybeans. It might allow them to cut nitrogen fertilizer applications, reducing both costs and the possibility of groundwater contamination. Nodulation is also likely to get a boost from mutant *B. japonicum* bacteria. L. David Kuykendall, a microbiologist at the Beltsville (Maryland) Agricultural Research Center and W. James Hunter, a microbiologist at the Crops Research Laboratory, Fort Collins, Colorado, have patented a mutant strain of the bacterium that improves nitrogen fixation in soybeans by increasing nodulation.

"In 2 years of field studies in Upper Marlboro, Maryland, we've obtained

DAVID NANCE

Undamaged soybean plant in geneticist Thomas Kilen's left hand demonstrates how effective insect resistance is in this experimental plant. (K5285-1)

KEITH WELLER

In a cold storage room, assistant curator of USDA's Soybean Germplasm Collection Claudia Coble examines seed to make sure it is correctly described. (K5236-7)

a statistically significant 25-percent increase in nodulation and a numerical increase in seed yield on plants inoculated with the new bacterium, as compared with another strain known as USDA 110," says Kuykendall.

Previously, USDA 110 was identified as the best strain for use as an inoculant—a commercial product consisting of the bacterial cells plus a peat-based carrier.

Seed yield increases were also obtained in field tests conducted by Urbana Laboratories in St. Joseph, Missouri, and Fort Dodge, Iowa. Tom Wacek, a microbiologist in charge of research and development for Urbana Laboratories, says the results are encouraging and promises more field tests.

New Germplasm, and Allelopathy

If U.S. soybeans of the future are high-yielding and resistant to insects and disease or have more nitrogen nodules than ever before, China may be at least partially responsible.

For the first time in history, the People's Republic of China has released a large quantity of soybean seed from its germplasm collection. The USDA Soybean Germplasm Collection at Urbana, Illinois, is the new home for the seed. Some 500 accessions have been acquired, to date, and 500 more are expected within the next year or so.

It's all part of a two-way information exchange between the United States and China. According to the agreement, the U.S. receives soybean germplasm in exchange for the opportunity for a Chinese scientist to work side-by-side with an ARS scientist for a year and the provision of new laboratory equipment for China.

Discussions leading to this exchange have been ongoing for nearly 10 years. ARS, the University of Illinois, Iowa State University, the Illinois Soybean Program Operating Board, and the Iowa Soybean Promotion Board were all partners in the final agreement with the Chinese Academy of Agricultural Sciences. Each will contribute $10,000 a year for 2 years to cover expenses.

"The overall benefits of this exchange will most likely be long-term," says Randall L. Nelson, curator of the Urbana soybean collection.

When Chen Yi Wu, a scientist from the Institute of Crop Germplasm Resources in Beijing, China, arrived in Urbana to work with Nelson, he brought with him seed from 500 soybean varieties gathered from 9 provinces in central China.

KEITH WELLER

Plant physiologist James Harper examines mutant soybean with two to four times the root nodules of average varieties. Nodules contain nitrogen-fixing bacteria. (K5239-1)

Test plots planted and harvested in 1992 gave Nelson his first opportunity to analyze the new seeds. But with just one growing season completed, the researchers are still uncertain of the benefits of these new accessions.

"There may be genes in these varieties to fight diseases and insects, and to improve oil and protein content," Nelson says, "but it will be a while before we really know what we have."

Once soybean seed is in the ground, producers wage constant battles with nature.

One fight is against weeds. Farmers traditionally use herbicides and tillage practices to control weeds. However, Reid Smeda, a plant physiologist in the Weed Biology and Management Research Unit at Stoneville, Mississippi, is looking at cover crops that exude toxic substances—allelochemicals—as an alternative method to fight weeds.

"It's known that some cover crops can suppress weeds, but it's uncertain how long the effect will last and how the soybean crop will be affected," Smeda says.

In the initial year of testing, field plots were planted with sorghum-sudangrass in early spring and killed using the herbicide glyphosate after the grass grew 6 to 7 feet high. The glyphosate was applied to soybean plots at a rate of 1 pound per acre 2 weeks, 1 week, and 1 day before planting with a no-till drill. Crop residue was flattened to minimize its interference with light received by emerging soybean plants.

"Weed suppression was greater than 90 percent up to 60 days after establishment," Smeda says. "And the soybean yields in plots where sorghum-sudangrass was killed 1 week or 1 day before planting were within 2 bushels per acre yield of a plot that had no cover crop and was hand weeded."

Poor soybean germination reduced yields in the plot planted 2 weeks after the cover crop was killed, although weed suppression in this plot was satisfactory. In an additional plot not planted with a cover crop, weeds were not managed. Yields from that

plot were the lowest of those included in the test.

Besides sorghum/sudangrass, researchers have ongoing tests with fall-seeded cover crops, such as rye, hairy vetch, and annual ryegrass. These are killed in the spring.

"Combining the allelopathic potential of cover crops and the capacity for the soybean canopy to shade out weeds may allow producers to use postemergence herbicide on an as-needed basis, rather than apply herbicides at planting or before planting," Smeda says.

Ensuring Adequate Water

Year in and year out, producers watch the skies, hoping the rainfall will be enough to produce a bumper crop. And it's this water that limits soybean yields year after year.

That's why Richard Cooper, an ARS agronomist at Wooster, Ohio, and Norman Fausey, a soil scientist at Columbus, Ohio, have developed a subirrigation/drainage system for soils that also sometimes need drainage of excess water. The system uses these same drainage tubes to put water back into the soil during periods of drought.

The tubes are generally 4-inch, corrugated plastic. The prevailing practice in the Midwest, according to Fausey, is to allow 40 to 80 feet between drainage lines. However, if the lines are to double as a subirrigation system, they need to be spaced 20 to 40 feet apart.

"The goal is to maintain a constant water table," says Cooper. "The ability to control water availability and maintain yields year after year is important to soybean producers."

"And a good water supply is essential," Fausey adds. "A surface reservoir that stores water, a major river or other body of water, or an existing high-capacity well are all possible options.

KEITH WELLER

Agronomist Larry Heatherly examines early maturing variety of soybean plants growing in a flood-irrigated field in Mississippi. (K5283-6)

"Ordinarily, drainage lines discharge into a stream, but to use the lines for subirrigation, a control valve is put on the discharge outlet. Then water is added into the drainage system through a standpipe—a vertical pipe that runs from the soil surface into the drainage system. The water flows back into the field and maintains the water table so there is a constant moisture supply at the root zone."

The biggest challenge in using this system, says Fausey, is knowing when to switch back and forth between the drainage and irrigation modes. So other scientists are working to develop a sensor that would be put in the system to help farmers make that decision.

The subirrigation/drainage system is already commercially available. In fact, it is being used on 20,000 to 30,000 acres in Michigan. But its cost may cause some farmers to shy away

from the idea. In Ohio, adding more lines to an existing drainage system may cost about $500 per acre, while starting from scratch may cost as much as $1,000 an acre.

However, the cost of the subirrigation/drainage system can be recouped through higher and more stable yields year after year, Cooper says.

KEITH WELLER

Under a rain-exclusion shelter, geneticist Jeffrey Tyler checks soybeans for the effects of drought stress during flowering. (K5276-1)

Eight years of studies have shown that soybeans irrigated in this manner yield an average 75 bushels per acre, compared to an average of 50 bushels for nonirrigated soybeans. And other crops will also benefit from a plentiful water supply. Corn yields may be boosted 50 to 60 bushels per acre, Cooper says.

Irrigation is more or less a must in the lower Mississippi Delta, where a considerable number of soybean acres are planted on clay soils. Without irrigation, yields are often less than 22 bushels per acre.

"It's common knowledge that irrigation will boost yields," says Heatherly. "But producers need to know how long they should irrigate and which varieties perform best under irrigation."

Field studies were conducted at Stoneville from 1987 through 1991 to determine when to stop furrow irrigation, how selected varieties perform under flood irrigation, and if early-planted soybeans respond to furrow irrigation.

The tests show that ending furrow irrigation at the mid-podfill stage is sufficient to maximize seed yield during dry years. "Irrigating beyond that time is not economical," Heatherly says.

Flood irrigations 2 days long during the period between beginning bloom and full seed stage in dry seasons increased yield by over 32 bushels per acre for unadapted varieties in maturity group VI.

Soybean varieties are grouped according to maturity dates. If planted before a recommended date, soybeans will flower earlier and for a longer period of time than normal, but the plants will abort the seed pods.

In 3 of 4 years, furrow irrigation more than doubled seed yield from maturity group III and IV varieties planted in mid-April to mid-May.

In a relatively wet year, only one irrigation still provided an average seed yield increase of more than 7 bushels per acre.

"A nonirrigated plot showed that early-season planting of these varieties may help avoid drought during the usually dry summer months," says Heatherly.

Another irrigation study indicates that furrow irrigation can be used to maximize yields and germination of soybeans grown for seed. So Heatherly recommends that growers looking for the highest quality seed for planting select seed that is produced by irrigated culture.

Sunlight's Critical, Too

The amount of sunlight is also a factor in soybean production. "Soybeans are very responsive to photoperiods, or the amount of daylight they receive," says Edgar E. Hartwig, a plant breeder at Stoneville.

But now, thanks to Hartwig's research, soybean growers in the southern states have a new variety that is much more flexible about daylength.

Named "Vernal," the variety is resistant to several major soybean diseases. It also has a unique flowering characteristic that allows it to be planted anytime from March to late August in the Rio Grande Valley and from mid-April to late June at Stoneville. Ideally, days should be 14-1/2 hours or longer when soybean plants emerge, to allow full growth before flowering.

Flowering usually occurs in 30 days or less after emergence, if days are sufficiently short. Day length is

influenced by the time of the year and proximity to the equator.

The new variety has a delayed flowering characteristic that permits good growth when planted under short-day conditions.

At Stoneville, if Vernal is planted in mid-May, it acts as a normal group VI, maturing in mid-October. If it's planted April 20, the crop will grow at a similar rate, but will mature in late September, like a group V variety. Yields, though, are higher when planted April 20, than in mid-May. The 4-year average for the irrigated April planting is 55 bushels per acre, compared to 45 bushels per acre for the irrigated mid-May planting.

"Vernal gives producers another management alternative," says Hartwig. "Because it can be planted earlier in the year, when soil moisture is optimal, farmers may be able to plant soybeans after another crop. They didn't have that opportunity in the past."

"While research aimed at improving soybean production is important, it would be for naught without the many food and industrial markets for the crop," says Howard Brooks. "As long as there is a demand for soybeans, ARS research can play a vital role in developing new and improved varieties, and finding the most efficient production methods."—By **Marcie Gerrietts,** formerly ARS.

To contact scientists mentioned in this article, write or telephone Ben Hardin, USDA-ARS-NCAUR, 1815 N. University St., Peoria, IL 61604; phone (309)681-6597, fax (309) 681-6690. ◆

Editor's note: In November, we will explore some of the many uses that are being developed for soybean-based products.

The USDA Soybean Germplasm Collection

When soybean breeders throughout the world need assistance with their breeding programs, they often turn to Randall L. Nelson.

Nelson is the curator of the U.S. Department of Agriculture's Soybean Germplasm Collection housed on the University of Illinois campus at Urbana, Illinois.

In 1991, the USDA Soybean Germplasm Collection at Stoneville, Mississippi, was consolidated with the Urbana collection.

"We get requests for germplasm from public and private breeders throughout the world," says Nelson. "During the past 10 years, we've averaged about 15,000 requests a year."

Generally, breeders requesting germplasm receive a packet of seed similar in size to those containing seeds for home gardening.

More than 14,000 germplasm lines—including varieties of both the common soybean, *Glycine max,* and the wild *G. soja*—are maintained in the collection. Stored in a controlled environment to ensure viability, seeds of *G. max* may be kept for 10 years and *G. soja* for 15. To maintain a supply of quality seed, aging specimens are periodically replaced by growing and harvesting new seed.

"Every time a variety is grown, more than a dozen traits are carefully monitored to maintain purity," says Nelson.—By **Marcie Gerrietts.**

KEITH WELLER

(K5237-19)

SCOTT BAUER

Streams of Conscientiousness

Scientists who once pursued only erosion control now also seek to restore fish and wildlife to ecologically damaged streams.

Now there's an extra half-mile reach of Hotophia Creek to fish in. And the fishing gets better each year, thanks to an ongoing Demonstration Erosion Control project.

Known as DEC, this project is an collaborative effort among Agricultural Research Service scientists at the National Sedimentation Laboratory (NSL), the Vicksburg District of the U.S. Army Corps of Engineers, USDA's Soil Conservation Service, and the U.S. Army Engineers Waterways Experiment Station of the Corps.

The project is a congressionally mandated effort to find environmentally sound solutions to problems caused by flooding, erosion, and sedimentation within one of the most channel-erosion-prone areas in the United States—Mississippi's Yazoo River basin.

Says nearby Batesville resident, D.R. Roberts, who is retired from USDA's Soil Conservation Service, "I caught a lot of bass in Hotophia Creek last spring. My friend owns these fields, and he lets me come down here and fish. This year, the fishing has improved considerably. I'm catching mostly what I call Kentucky bass—the largest about 2-1/2 pounds."

ARS hydraulic engineer Doug Shields works at the NSL, which is located at Oxford, Mississippi. He says, "Hotophia Creek may not be the fishing mecca of the United States, but our sampling shows the number of catches increased from 162 to 746. And the fish caught were 10 times heavier, with twice as many species in the catch. And even more important, fish length almost doubled, on average, in just one year."

Like many streams in this part of the state, Hotophia Creek is wide, shallow, and sand filled downstream. Upstream, the channel is relatively narrow and deeply incised, with bank heights often exceeding 20 to 30 feet. Because of erosion that followed unwise land management practices, reservoir construction, and straightening and deepening of channels, many present-day channels in northern Mississippi are as much as 10 times wider than they were in the 1930's.

SCOTT BAUER

High-altitude photography helps document changing conditions—particularly of channel systems—throughout DEC project watersheds. Here, soil scientist Earl Grissinger (right) and geologist Joe Murphey analyze aerial photographs of the Goodwin Creek area. (K5218-03)

Bed and bank instability are major problems.

Hotophia Creek, which is in Panola County between Oxford and Batesville, drains about 22,400 acres— 35 square miles. Last year, a section of it became part of an experiment to discover how best to restore fish and wildlife to stream habitats.

According to Shields, "Before the channel stabilization work began, Hotophia Creek was yielding thousands of tons of sediment per mile of channel. With time, restoration will reduce this to more acceptable levels."

Why a Sedimentation Lab?

According to ARS hydraulic engineer George Foster, director of the National Sedimentation Laboratory, "When the lab opened in 1959, its mission was to find solutions to environmental problems caused by soil erosion, poor water quality, and sedimentation—especially those problems related to agriculture.

"Recently, emphasis on water quality, ecology, and environmental protection has increased. The stream habitat restoration work on Hotophia Creek is a good example of this.

"One of the greatest stream pollutants, by volume, is sediment from field and channel erosion, and Mississippi is the nation's worst-case scenario," says Foster. "Each year, the Mississippi River carries over 300 million tons of sediment to the Gulf of Mexico. Such eroded sediment does irreparable damage. It clogs streams and ditches, bottomlands become flooded, and, as water quality declines, fish and wildlife habitats degrade or disappear."

The NSL is strategically located in the northern part of the state, within the Yazoo River Basin, in the hills above the Mississippi River alluvial plain. Conservation principles shown to work in this area will help in stabilizing eroding streams in many other geographic areas, as well.

Soil Conservation Service (SCS) agronomist Bill Lipe, who has worked with ARS scientists at the NSL for 4 years and is the SCS liaison there, says, "Much of the pioneering work on agricultural pollution was done by National Sedimentation Laboratory scientists. In the Southeast, the lab has

Small waterfalls called headcuts gouge stream channels ever deeper as they move upstream. The variety and vigor of the insects that biologist Sam Testa collects will reflect the level of environmental harshness or pollution in this stream. (K5213-3)

long been a leader in research on the movement of pollutants from the land to streams and lakes."

Foster adds, "The DEC project started with six watersheds in 1984. Today, the $30 million-per-year project has expanded to 15 watersheds. It is one of NSL's most important and impressive research projects, involving thousands of miles of streams. And it's an excellent example of ongoing, directly applied research and technology transfer."

Keeping Sediment Out of Channels

One of DEC's missions is to reduce erosion and keep sediment out of Delta streams and lakes. Stream channel control measures include constructing spur dikes, grade control structures, riprap bank protection, and small flood-control reservoirs.

Spur dikes are fingers of stone that extend into the creek. Grade-control structures, made by driving sheet piling across a stream and placing rockfill downstream, create small waterfalls and control channel erosion upstream. Riprap revetments are layers of large stones, or facings, placed along streambanks to prevent erosion and instability.

Foster says one dramatic success story is the 8.3-square-mile Goodwin Creek Research Watershed, located in one of the original project watersheds that predates DEC. About 20 miles west of Oxford, its 14 fully instrumented gauging stations—each costing a quarter of a million dollars—were built by the Corps. It's one of the best instrumented and most intensively studied watersheds in the United States. The information gathered from studies at Goodwin Creek on rainfall, runoff water, sediment yield, and land use supports sediment transport research at other DEC project watersheds.

For every storm, each gauging station collects a variety of data, such as temperature, amount of water generated, and movement of gravel in the stream. Each station has a system to automatically collect discharge samples used to calculate sediment concentrations and sediment yield. Microcomputers relay this information back to the NSL every 30 minutes. Samples are bar-coded at the collection site and analyzed back at the lab.

"Goodwin Creek shows us how to do the best job of preventing erosion along channels at the least cost," Foster adds. "Data gathered there will be used as prototype data for all future DEC activities."

Like Hotophia Creek, the lower end of Goodwin Creek is getting a facelift. Between gauging stations 1 and 2 on Goodwin Creek, part of the DEC project team is working on measuring surface water quality and restoring streams to stable ecosystems. ARS ecologist Charlie Cooper leads an aquatic ecology group that includes Doug Shields and ARS ecologist Scott Knight.

According to Shields, DEC streams don't usually have harmful water quality. The constraints on the aquatic habitat are more physical: Erosion causes the streams to be too shallow and sandy and makes the hydrology too flashy, so flows peak and fall too rapidly.

Says Cooper, "Early in our DEC evaluation, we found that the lack of stable habitats limited fish populations. During heavy rainfalls, habitats are scoured or hollowed out, covered with silt or sand, or moved. Because suitable habitats are lacking, entire annual hatches of fish are missing. And during dry periods, the water level is too shallow to support fish populations."

Shields, who studies stream restoration, was with the Corps for 12 years before coming to the NSL in 1990. He says, "What we're trying to correct is an environment that has been severely traumatized. When we looked at habitats created by structures used to stabilize against erosion, we found the

SCOTT BAUER

Biologist Sam Testa (right) and research assistant Rick Fauteux check growth of young willow trees sprouting from a row of 5-foot-long posts set in this sandbar. Such revegetation helps restore riparian zones along highly eroded channels. (K5210-18)

structures were not really optimal for restoring stream channels."

Even after channels are stabilized, many of the streams in DEC watersheds are extremely shallow and have little tree canopy. Shields says, "From an environmental standpoint, we'd like to see occasional deep pools with lots of shade canopy and woody debris.

"So we designed a study of seven stream reaches—each about 6-tenths of a mile long. Hotophia, Goodwin, and Martin Dale Creeks are being restored. Peters Creek, Bobo Bayou, and Martin Dale Tributary were left untreated. And Toby Tubby Creek, which was not badly eroded and flows through forested wetlands, is being used as a reference site."

Goodwin Creek landowner William E. Leigh, whose property surrounds the DEC stream restoration site, says, "Goodwin's a little creek most of the time, except after a heavy rainfall. It's too soon to tell how well the restoration will work, but I think it'll do the job. Already, plenty of beavers have been busy, damming up the lower end of the creek and making an even deeper pool." Leigh worked for the Corps for 15 years as a mechanical and electrical engineer before retiring.

Knight finds that "one of the most rewarding aspects of DEC is the intermingling of engineering and environmental expertise to benefit both aquatic habitat and channel stability."

To restore habitats along Goodwin Creek, Shields and the other researchers used three techniques. "We put in spur dikes, pointing them alternately up and down the stream, added a low ridge of stone along the sandbank, and then planted 3,400 willow trees along the stream.

The spur dikes have increased deep-pool habitats by 200 percent.

"We sampled fish in the spring and fall of 1991, before the restoration, and again 1 year later," says Shields.

The restoration techniques worked. Before restoration, the largest spotted bass weighed less than half an ounce; a year later, the largest was 2 pounds. The largest long-ear sunfish weighed 1.5 ounces before the restoration, and 10 ounces afterwards.

Knight adds, "The number of species increased, too. Before restoration, we found 15 species of fish; afterward, 24. New species included smallmouth buffalo, channel catfish, and largemouth bass. And we've found five different species of catfish and four of gar."

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Sediment from a newly formed gravel riffle will tell Sam Testa much about insect life in this restored reach of Goodwin Creek. (K5207-13)

Near some stone projections, the scour holes that developed were 1 to 4 feet deep and about 8 feet across. "Stream areas classified as pools nearly doubled, and these pools made all the difference," Shields says. "Had we pushed the system further, the biological response could have been even greater."

Filming a Bird's-Eye View

National Sedimentation Laboratory scientists use a Panasonic 3CCD S-VHS camera to videotape each segment of every creek in the DEC project area from a height of 2,400 feet, at a speed of about 100 miles per hour.

At full-lens field of view, this gives a 2,000-foot-wide film path with a resolution of 2.86 feet per pixel (data point in the picture element).

At full 16-X telephoto magnification, the flight film path width can be reduced to 125 feet, with a resolution of 2.25 inches per pixel.

Where precise measurements are needed, individual scenes are georeferenced using Global Positioning System procedures.

According to ARS soil scientist Earl Grissinger, LANDSAT satellite imagery records the average spectral characteristics of a 30- by 30-meter area (about a 100-foot square).

He says that for a lot of applications, this is very satisfactory. It's sufficient for broad land classification for large areas. Where more detailed information is needed, CCD-type video imagery is being used.

Video imaging has the advantage of being operator dependent. Data can be collected at any scale—within reason—that is needed.

Grissinger says, "These pictures, taken at 1/2000th-of-a-second shutter speed, can then be frame grabbed, downloaded at the National Sedimentation Laboratory, georeferenced, and analyzed for such things as channel plugging, widening, deepening, land-use changes, and structural performance.

"Theoretically, under ideal conditions, we can detect the movement of a single piece of riprap."—**Hank Becker,** ARS.

Adds Knight, "We have found that dikes are better for fish habitat than other types of bank protection structures used in the DEC program. They promote waterflow patterns conducive to a wide range of water depths and velocities.

To collect data on fish populations, the team uses an electrical stunning device, collects the fish in nets for examination, and releases them as soon as possible. Workups on larger fish typically include identification; a visual inspection for hybridization, lesions, other anomalies, and length measurement. The team preserves and bags smaller fish for laboratory workups.

But this "electrofishing" may soon be passé, replaced by state-of-the-art acoustical sensing. The NSL has a cooperative research agreement with the University of Mississippi's Jamie Whitten National Center for Physical Acoustics at Oxford.

A Biotic Inventory

Says Cooper, "As part of our long-term evaluation of the effects of DEC channel stabilization, we're also characterizing—that is, keeping data describing the environmental changes that occur on—thousands of stream miles. We use the data to develop an index of biotic integrity."

This index is a measure of stream health based on samples of fish populations. Since fish are sensitive to their environment, the index reflects water quality and physical stream characteristics such as water depth and velocity, channel width and depth, streambed composition, and bank vegetation. Because the index is computed from several different variables that describe a fish sample, it's much more sensitive to changes than any one measure.

The scientists have detailed 44 sites on 15 different watersheds, including Hotophia and Goodwin Creeks.

Sam Testa, an ARS biologist who works with Cooper, adds, "As part of this work, we sample different plant and animal habitats. When we sample invertebrates, we take gravel and sand cores from stream bottoms and measure the organisms they contain. We also scrape the rocks, looking for invertebrates such as mayflies. The number and types of animals indicate their tolerance of pollutants or to the harshness of environment."

SCOTT BAUER

Benthic animals—including microbenthos like these examined by research assistant Belinda Garraway—are a key food source for fish. Benthic populations are highly sensitive to water quality and disturbances caused by accelerated erosion and sedimentation. (K5217-13)

The ARS team is working with fish biologist Steve Ross at the University of Southern Mississippi, Hattiesburg. Ross is compiling a database of state fishes. The team hopes to collect enough information so future efforts can be measured against this database.

The team also cooperates with the Mississippi Department of Wildlife, Fisheries, and Parks. "Any unusual catches are preserved and sent to the state museum at Jackson," Knight says.

An anticipated result of this project will be the adoption of these stream restoration practices as a routine part of DEC projects. So in the DEC and similar projects, instead of simply combating erosion, construction can also include stream corridor habitat restoration with little additional cost.

"In fact," says Cooper, "as a result of our study, the Corps has already modified standard designs in DEC and extended the tips of spur dikes to improve habitats. And both the U.S. Department of the Interior's Bureau of Land Management and the Tennessee Valley Authority have asked for help in transferring the technology to improve their unstable streams."

Shields says that sport fishing is one of the most popular activities in the United States. And fishermen prefer stream fishing to lake fishing, according to a public opinion survey by state fishery biologists.

"Southeastern streams are harbors of ecological diversity—much like the tropical rainforests. Even if we don't develop a sport fishery here, the taxpayer will benefit, because what we learn about ecology and species diversity has a value in and of itself.

"Each year, stream habitat restoration is growing in popularity around the world. Some western states have an adopt-a-stream program to clean up and restore the health of streams. This restoration project put the DEC program in the forefront of a research area with worldwide interest.

"Now that Hotophia and Goodwin Creeks have been restored, Martin Dale Creek is scheduled next. It's already about 15 feet deep and not very wide, so all we're going to do there is plant willows along the banks. That will begin next spring."

What's the Impact, Overall?

Restoring stream habitat isn't the only new and innovative technology

being used in the DEC project. NSL soil scientist Earl Grissinger is an expert on DEC and its history. He looks at how changes in land uses affect water quality and at indicators of channel erosion. And he works closely with the U.S. Army Engineers Waterways Experiment Station in developing plans and procedures for long-term monitoring of the efficiency of the DEC program.

Grissinger explains that the NSL is involved in promoting more efficient use of existing data to meet the streambed and channel construction design needs of action agencies that build waterway structures. Modelers will be able to use DEC data in simulations of channel processes—anywhere in the United States.

To better organize and integrate the enormous amount of data collected from the DEC projects, the scientists are planning to use Geographical Information Systems. GIS is a grid-based system that uses computers to combine extensive data on diverse features, including soil type and land- use characteristics, into spatial databases. This facilitates model simulation, as well as better collection and organization of new data for use by action agencies.

A data set complementary to LANDSAT is currently under development to aid in interpreting land-use data and other needed information, and video and laser technology are being adapted to NSL needs. ARS pioneered the agricultural application of video imaging technology at the agency's Remote Sensing Laboratory in Weslaco, Texas.

Grissinger says, "Scientists can now fly over DEC project areas and remotely collect and record, in minutes, data that would have required thousands of hours of manual labor. "

This past spring, NSL hydrologic technician Keith Parker, hydrologist Bill Blackmarr, and geologist Joe Murphey spent several weeks aerially videotaping all the streams in the DEC project watersheds—more than 1,100 miles of restored channels.

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This massive concrete and stone structure allows the water in Hotophia Creek to drop to a lower elevation without eroding the streambed. Researcher below spillway is collecting water quality samples for later study. (K5215-7)

According to Murphey, "The videotape records allow us to monitor the performance of the various channel protection measures installed by the Corps and SCS in the DEC project watersheds from Memphis to Vicksburg."

For all the DEC watersheds, the general problem areas have been characterized and classified as to their severity. These include urban flooding, sedimentation in the floodplain, channel filling and obstruction, upland erosion, and bank caving.

"Many of these problems are interactive," Grissinger explains. "For example, sediment from severe upland erosion—if deposited in critical channel reaches—can cause flooding." To monitor sediment, the U.S. Geological Survey is currently collecting discharge samples from 12 of the 15 DEC watersheds.

"The charge given to DEC is unique, emphasizing as it does evaluation of procedures in use today and practical demonstration of research findings. And DEC offers a unique opportunity to assess the strengths and limitations of current action agency procedures for abating watershed-scale problems."—By **Hank Becker,** ARS.

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SCOTT BAUER

(K5266-9)

Yesterday's newspaper or last year's telephone directories could turn up again in compost pellets rather than the landfill.This is good news, because whether they live in Devil's Lake, North Dakota, or New York City, Americans throw away an average of 1.6 pounds of paper a day. This paper makes up about 40 percent of the solid waste that goes to landfills each year.

Jim Edwards, a soil scientist with ARS in Auburn, Alabama, is working with manufacturers of pelletizing equipment and others to process newspapers, phone books, and other types of waste paper. The small, 3/8-inch-diameter pellets could be spread on fields by machines that currently dispense fertilizer.

Edwards is also exploring the possibility that some inks may have pesticidal qualities because the shredded newspapers seem to inhibit fungal diseases, as well as weeds such as crabgrass.

With a $20,000-a-year grant from Auburn University for a 2-year recycling project, Edwards gets waste copies of the local newspaper in Auburn, while his telephone books were collected in a special curbside project in his county.

After shredding, the phone books were plowed into the soil this past spring to grow corn, soybeans, and cotton. Newspapers were mixed with chicken litter, and waste from urban yards and local cotton gins was recycled as part of Edwards' co-composting of mixed solid wastes from farm and town or city.

Edwards says that one problem with paper is that its carbon-nitrogen ratio of 150:1 isn't even close to the 30:1 ratio desired for composting. So in the long run, he envisions pelletizing paper along with another waste product high in nitrogen, such as manure, food waste, or yard waste.

He initially began his research with the idea of loosening soil so cotton roots could penetrate deeper. In his part of Alabama, a compacted layer of soil often keeps roots from penetrating more than 6 inches. Disking paper pellets into the earth would separate soil particles and help reduce this compaction.

But in the sands of West Texas, cotton roots don't meet resistance.

"We don't have any particular soil problem growing cotton, other than lack of water," says Jimmy Apel, USDA Soil Conservation Service coordinator of the Big Country Resource Conservation and Development (RC&D) Area, Inc., in Sweetwater, Texas.

The Texas panhandle is a land of cotton, cattle, and oil—in the heart of what was once the Dust Bowl. In addition to establishing job opportunities, Apel says the 12-county Big Country RC&D Council has three priorities: reducing erosion, improving water quality, and recycling waste materials. "Recycling paper pellets hits all three."

Apel explains that large pellets—2 to 4 inches long with a 3/4-inch diameter—hold down the highly erodible soil and break the wind's impact. "We expect to have less soil blowing away when it's dry and less sediment carried in the streams when it rains."

He is counting on paper pellets to control erosion on more than a million acres of farmland in his area.

The pellets have other advantages over shredded paper: The compacted paper takes longer to decompose and is easier to transport, allowing more pounds of newspaper per truckload.

Apel sees a future for the pellets nationwide, with cities buying portable equipment to grind paper and extrude it as

SCOTT BAUER

Shredded paper trash destined for waste management studies is examined by ARS soil scientist Jim Edwards (left) and Auburn University's Jim Bannon. (K5258-20)

pellets. He says the alternatives for waste paper disposal in his area are either burying it in the landfill or paying someone to haul it long distance to paper recycling plants on the Gulf Coast.

We've Got to Get the Lead Out

Edwards is cooperating in the Big Country RC&D's paper pellet project. He is analyzing the area's waste paper to see if lead or other heavy metals are present in the inks in amounts that would be harmful to the environment. He says that printers are gradually eliminating such heavy metals, but he has to check to be sure that certain locally produced materials aren't the exception to the rule.

To analyze for levels of toxins and nutrients in paper waste from homes, Edwards has volunteers in various states collect and send in samples of waste paper. For example, a family in Devil's Lake, North Dakota, saved all their waste paper—computer paper, cereal boxes, newspapers, junk mail, frozen food packages, etc.—for a month and shipped it to him.

SCOTT BAUER

With a sieve, soil microbiologist Don Kaufman searches for residual biodegradable plastic materials in field soil samples. (K5264-16)

The highest lead level found in the North Dakota paper waste was in the frozen food packages and other food container cardboard, Edwards says.

"There's no risk to consumers of those foods because the lead is 'locked' into the packaging; the potential risk comes when the packaging is shredded and mixed into soil. However, it's likely that the risk will be brought down to an acceptable level when the packaging's lead content is averaged by mixing it with other waste paper and cardboard that has little or no lead."

Curbing Wind Erosion

ARS scientist Donald Fryrear wants to determine if leachates—materials dissolved out by action of percolating liquid—from the paper will bond sand particles so that erosion will be controlled for a long time.

Disappearing Landfills

Texas is like many other states in that some landfills are closing because of strict new regulations from the U.S. Environmental Protection Agency and state or local governments.

Some predict that only regional landfills will be able to afford the enormous construction costs of complying with groundwater protection regulations that went into effect on October 1, 1993. The new municipal solid waste rules may make the costs of operating a landfill prohibitive for many small communities.

"Two or three counties may want to consolidate their landfills into one regional landfill," suggests Jimmy Apel, coordinator of the Big Country Resource Conservation and Development Area, Inc., in Sweetwater, Texas. He says landfills in the cities of Blackwell, Loraine, Merkel, Sweetwater, and Rotan were all to be closed by October 1.

"Once they're closed, people can't bring garbage or newspapers to them, though they can still bring tree limbs," he says.

Some of the landfill sites will become transfer stations where garbage and yard waste will be compacted and loaded onto 18-wheeler trucks for delivery to regional landfills. For example, Sweetwater will probably ship its waste 42 miles to Snyder, or 66 miles west to Big Spring.

Apel says that a landfill would need to serve 50,000 people in order to be economical. "Tipping or unloading fees are rising from $3 a ton to $8 to $15 a ton in this area," he says. While tipping fees for most landfills around the country are below $30, fees for some landfills on the East Coast are fast exceeding $70, and for New York City they are now at $146 per ton.

"Another part of the new environmental laws is a mandatory reduction of solid waste disposal: 10% by 1995, 25 % by 1997, and 40% by 2000," Apel adds.—**Don Comis,** ARS.

He says, "Using paper pellets to control wind erosion could significantly affect sandy soils in many parts of the United States."

Fryrear, a dust storm expert based at Big Spring, Texas, is working with Edwards. Fryrear will do wind tunnel tests to get preliminary estimates of how many pellets will be needed per acre to control wind erosion. He will also provide space for field tests if the paper passes toxicity tests.

To control wind erosion in this area, farmers normally have to plant winter cover crops and leave crop residue on the surface.

But the problem with cover crops in West Texas is that rainfall is so scarce—18 inches or less a year—that farmers can't afford to give any soil moisture to cover crops. If they do, the cotton crop suffers the next year. So paper pellets could take the place of the cover crops and crop residue, reducing both soil erosion and evaporation of soil moisture.

Apel says that after the toxicity and wind tunnel tests are done, test plots will be established with funds from a $6,500 grant awarded to the Big Country RC&D Area.

Next, information gathered from the test plots will be used to set up a larger field demonstration. Apel says he will start with 1-acre sites and expand to 40- to 100-acre fields. "Then, we will meet with farmers and interested organizations to show them how to use recycled paper pellets."

Edwards is also assisting in a similar project in North Dakota—a land of wheat, wheat, and more wheat.

The Northern Plains RC&D Area in Devil's Lake has wind erosion problems similar to those of west Texas and the same low rainfall of 18 inches or less a year.

Keith C. Van De Velde, coordinator of the Northern Plains RC&D Area, says that he is interested in the paper pellets mainly for wind erosion control and recycling. All the landfills in his six-county area will be closed this year.

The area has only 45,000 people and no matter how much paper they read or write on, Van De Velde realizes they will not generate enough waste paper to cover more than 4,000 acres of the area's 4 million acres of wheat fields with 5 tons of paper per acre each year.

"The plus side of this is that, unlike urban areas, we can recycle all of the waste paper from these six counties without fear of producing unwanted pellets and make no trips to the landfill," Van De Velde notes.

SCOTT BAUER

Research assistant Leanne Teerlinek prepares a test of compost maturity. (K5263-20)

He has a $23,000 EPA grant, plus an additional $2,000 from the Regional Planning Council for the RC&D. He plans to apply the paper pellets to eight 1-acre demonstration sites throughout his area and lead farmers on tours of the sites. Van De Velde expects to get both weed suppression and moisture retention benefits.

"The pellets absorb water like thousands of sponges, preventing water evaporation while allowing plant roots access," he says.

Jerry Allen, the North Dakota project officer at the Region VIII EPA office in Denver, Colorado, says that pelletizing paper for land application is new in his area. He says that Van De Velde had the paper pellets made at a plant that normally pelletizes feed for livestock. "He didn't have to use any new technology or techniques."

Allen says that projects such as these are models for ways to divert vast quantities of material away from local landfills, extending their period of usefulness and reducing the costs involved in transporting material to regional landfills.

"The potential exists for finding good uses for waste paper across the country, with the help of data collected from small projects like this one," he says.

Urban/Farm Interface Can Help

ARS scientists are also working with Rodale Institute Research Center scientists in Kutztown, Pennsylvania, on developing similar recycling cooperation between farms and towns. ARS microbiologist Donald D. Kaufman, stationed at Rodale, advocates this approach.

"Instead of trying to find scarce municipal land for more landfills or composting sites," Kaufman suggests, "why not preserve nearby farmland for on-farm composting of safe waste?"

Kaufman is on assignment at Rodale 4 days each week from the ARS Soil Microbial Systems Laboratory in Beltsville, Maryland. He serves as a research coordinator at the Rodale Institute, which is a private, nonprofit organization advocating organic farming and other alternative agricultural techniques.

Kaufman says that composted paper and yard waste improve the soil condition by adding carbon and loosening soil particles. The carbon feeds and increases the numbers of beneficial bacteria.

Kaufman says he and others at Rodale are researching the feasibility of producing salable composts from mixes of farm and urban wastes.

ARS scientists at Rodale are incorporating just about everything into compost piles, including paper dinner plates from the Rodale Press' employee cafeteria and biodegradable forks, knives, and spoons made from an experimental, starch-based plastic substitute. The plates and utensils are mixed with leaves. Other starch-based plastic materials in the compost heap include votive candle cups and golf tees.

Newspapers are being tested, too, but only after being used as bedding in dairy barns. Leaves are composted with the used bedding, as well as with poultry litter.

The scientists have grown spinach and oats on the various composts and are currently trying corn and peppers.

Kaufman will give composted wastes a new twist: adding microbes that aid in preventing plant disease and promoting plant growth. ARS scientists and others have been identifying and genetically engineering microbes to replace chemical pesticides and growth regulators, but they've always had the problem of finding a practical way for farmers to apply the microbes to their crops.

Now Kaufman and microbiologist Patricia D. Millner, head of the Soil Microbial Systems lab, have the idea of piggy-backing them in compost. "It might be a ready-made medium that can support the microbes and carry them to the fields or nurseries," Kaufman says.

This fall, Kaufman and the Rodale scientists began evaluating the chemical and biological components of liquid leached from compost piles to determine if there are any environmental hazards.

The Soil Microbial Systems lab, formerly called the Biological Waste Management Laboratory, is internationally known for its development of the Beltsville Aerated Pile Method, in which sewage sludge is composted with wood chips. This method is now used by more than 150 cities in the United States.

SCOTT BAUER

Jim Edwards (left) and Sandy Haskell of Recycle America in Birmingham, Alabama, discuss the use of paper in agricultural applications. (K5259-17)

James F. Parr, who is ARS' national program leader for dryland agriculture and soil fertility research, says "the main advantage of the Beltsville Aerated Pile Method is producing a safe, stable, humuslike material that can be easily handled, stored, transported, and applied. Composted materials serve primarily as soil conditioners because they release nitrogen and phosphorus so slowly."

The Beltsville scientists have conducted research showing that sewage sludge can be used to produce beneficial and safe composts, provided it has a low content of heavy metals. Such good-quality composts can be used in potting media and to grow any crop, including vegetables. They can also be used on turfgrass farms and in the reclamation of marginal or degraded lands.

Composting research will soon return to Beltsville in the form of mixed waste co-composting. Waste research plots will be established to demonstrate safe ways of recycling urban, industrial, and rural wastes. The plots are part of a broad-scale sustainable agriculture project, according to Donald Bills, who chairs the project's coordinating committee at Beltsville.—By **Don Comis,** ARS.

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Catfish Fillets Checked for Flavor

With its gangly whiskers, bulging eyes, and bottom-feeding reputation, the catfish may not be the most comely of fish. But its tender, mild-tasting flesh is fast appearing among trendy restaurant entrees.

In 1992, about 460 million pounds of the fish were processed, almost five times the amount 10 years ago, says Donald W. Freeman, a food technologist for the Agricultural Research Service. Of the top 10 seafoods consumed in America, catfish currently ranks sixth, while tuna is first.

Like most seafood, however, frozen, stored catfish is highly susceptible to rancidity, says Freeman, who works with ARS' Aquaculture Research Project in Tishomingo, Oklahoma.

In storage, oxygen seeping into frozen, processed fillets causes the breakdown of fats. When this happens, several byproducts called aldehydes produce rancid flavors and odors.

"Delaying the onset of these harmless but unpleasant flavors in frozen catfish products is a major concern of processors," says Freeman. "They've told us that they can't store their fillets beyond about 6 months."

In Mississippi, Arkansas, or Alabama, processors often require more leeway in which to distribute their products to emerging but distant markets in California or New York—states where catfish hasn't traditionally been popular.

"Those areas are being targeted as new territory," says Charles Langley, director of quality inspection and technical services for Delta Pride, a catfish processing plant in Indianola, Mississippi. "But we have to change catfish's image in those regions so it can compete with other more traditional seafood species."

Most processors rely on taste panels to help them check for signs of rancidity in inventories before rotating them accordingly. But extensive flavor testing of inventories can be difficult, Freeman says, because tasters get tired, which could affect flavor scores.

Objective alternatives like gas chromatographic (GC) or thiobarbituric acid (TBA) analysis—that gauge rancid compounds—offer promise because they detect rancidity in fillets at levels below a taster's threshold. This would help processors detect rancidity during storage sooner and more extensively than is possible by taste-testing alone.

But objective data generated by these approaches doesn't always correlate with scores by taste panels.

In 1992, Freeman and the late food technologist James O. Hearnsberger of Mississippi State University tackled this problem in a study that confirmed that rancidity occurs more rapidly and abundantly in catfish fillet dark meat than in white meat.

Freeman says that higher aldehyde concentrations in dark meat are due to its greater content of fat, iron, and copper combined with the availability of oxygen at the surface of fillets. Iron and copper act as catalysts in fat breakdown.

And since white meat makes up most of the fillet, objective testing of tissue from the whole fillet weakened the rancidity-related numbers generated by GC or TBA analysis.

So by sampling only dark meat, Freeman says, "we've developed an approach that correlates very well with taste panel flavor scores." Based on recent tests, "GC or TBA analysis can account for over 90 percent of the rancid flavors that people detect."

Applying this knowledge, he says, should give industry an objective tool for evaluating how well antioxidants, new packaging techniques, or handling practices prolong shelf-life.—By **Jan Suszkiw,** ARS.

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Objective tests that measure rancidity will let food processors know how well antioxidants, new packaging, and better handling methods maintain flavor in catfish fillets. (93-8)

DONALD FREEMAN

Science Update

Workout Tones Up More Than Muscles

Regular aerobic exercise helps improve glucose tolerance in people who are at risk of developing diabetes—even if they don't lose weight. A 12-week study of men and women over age 50 showed exercise itself improved the body's ability to respond to insulin so that glucose moved readily from the body into blood cells. The volunteers exercised on a stationary bicycle at 50 to 75 percent of their maximum aerobic capacity for 4 days a week. While they did not lose weight, their bodies cleared 11 percent more glucose from their blood with the same amount of insulin at the end of the study than they did at the beginning. *Virginia A. Hughes, USDA-ARS Human Nutrition Research Center on Aging at Tufts, Boston, Massachusetts; phone (617) 556-3079.*

Genetic Sunscreen for Crops

Scientists know too much sun destroys a leaf protein, D1, essential in photosynthesis. So ARS and the Boyce Thompson Institute for Plant Research, Ithaca, New York, are pursuing studies to give crops stronger genes for making natural sunblocker compounds—called flavonoids—on leaves. The tactic could ward off photosynthesis slowdown from natural solar excesses—such as at mid-day in summertime. *Autar Mattoo, USDA-ARS Plant Molecular Biology Laboratory, Beltsville, Maryland; phone (301) 504-5103.*

Dairy Model Available

Dairy farmers can get help on management decisions from DAFOSYM, an ARS-developed computer model that simulates dairy farm operations. Farmers can use the program to select, for example, the most economical type of silo. The scientists have distributed over 150 copies of DAFOSYM to farmers, farm consultants, cooperative extension agents, and other researchers. *Richard E. Muck, U.S. Dairy Forage Research, Madison, Wisconsin; phone (608) 264-5245. C. Alan Rotz, USDA-ARS Fruit and Vegetable Harvesting Research, East Lansing, Michigan; phone (517) 353-1758.*

BARRY FITZGERALD

Asian cockroach. (K2252-8)

Bait Makes Pests Bearers of Bad News

Cockroaches and ants could be delivering bad news to their colonies in a couple of years. The "news" will be a bait carrying a new class of insecticides originally discovered and patented by ARS scientists. ARS has granted a license to Griffin Corp. of Valdosta, Georgia, to produce and market the new compounds, called fluorosulfonates. Insects that eat the compounds don't die right away; they have time to first take them back to the nest to share with their fellows. *Robert K. Vander Meer, USDA-ARS Medical and Veterinary Entomology Research Laboratory, Gainesville, Florida; phone (904) 374-5918.*

Test-Tube Livestock Finding Safer Berth in the Lab

A new growth medium successfully supports animal embryos through a crucial stage of incubation in culture tubes. When genes are inserted into embryos, extreme care is required so the embryos keep developing normally. ARS scientists have developed a single growth medium—fluid with nutrients and salts—to replace four media currently used. With the single medium, there's less chance of contamination and shock to eggs and embryos, and it's simpler and easier to work with large numbers of eggs and embryos. *Ross A. Waterman, USDA-ARS Gene Evaluation and Mapping Laboratory, Beltsville, Maryland; phone (301) 504-8543.*

Computer Model To Help Save Streams' Sparkle

A new computer model, Opus, is available from ARS scientists to help farm advisers, managers, and scientists select the best practices for keeping pesticides and fertilizer out of water supplies. This state-of-the-art model is designed to help determine how much of dissolved farm chemicals will be transported to surface and ground water. Opus simulates water movement on and through soil, along with plant growth, water use, erosion, runoff, and chemical movement. Opus requires an IBM-compatible computer and runs best if the computer has a 386 or faster microprocessor and a math coprocessor. *Roger E. Smith, USDA-ARS Water Management Research Unit, Fort Collins, Colorado; phone (303) 491-8263.*

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Upcoming in the November Issue

☛ Growers would like to stage a comeback for the East Coast pear industry. ARS scientists are abetting this plan by quenching fire blight and subduing the pesky psylla.

☛ New products and improved old ones—all from soybeans—open new markets and increase the use and value of this major U.S. crop.

☛ A recent study tries to answer the question: Which is the more beneficial source of the antioxidant vitamins C and E—food or dietary supplements?